# The case for prior cryo-conditioning in the Highlands of S. E. Australia

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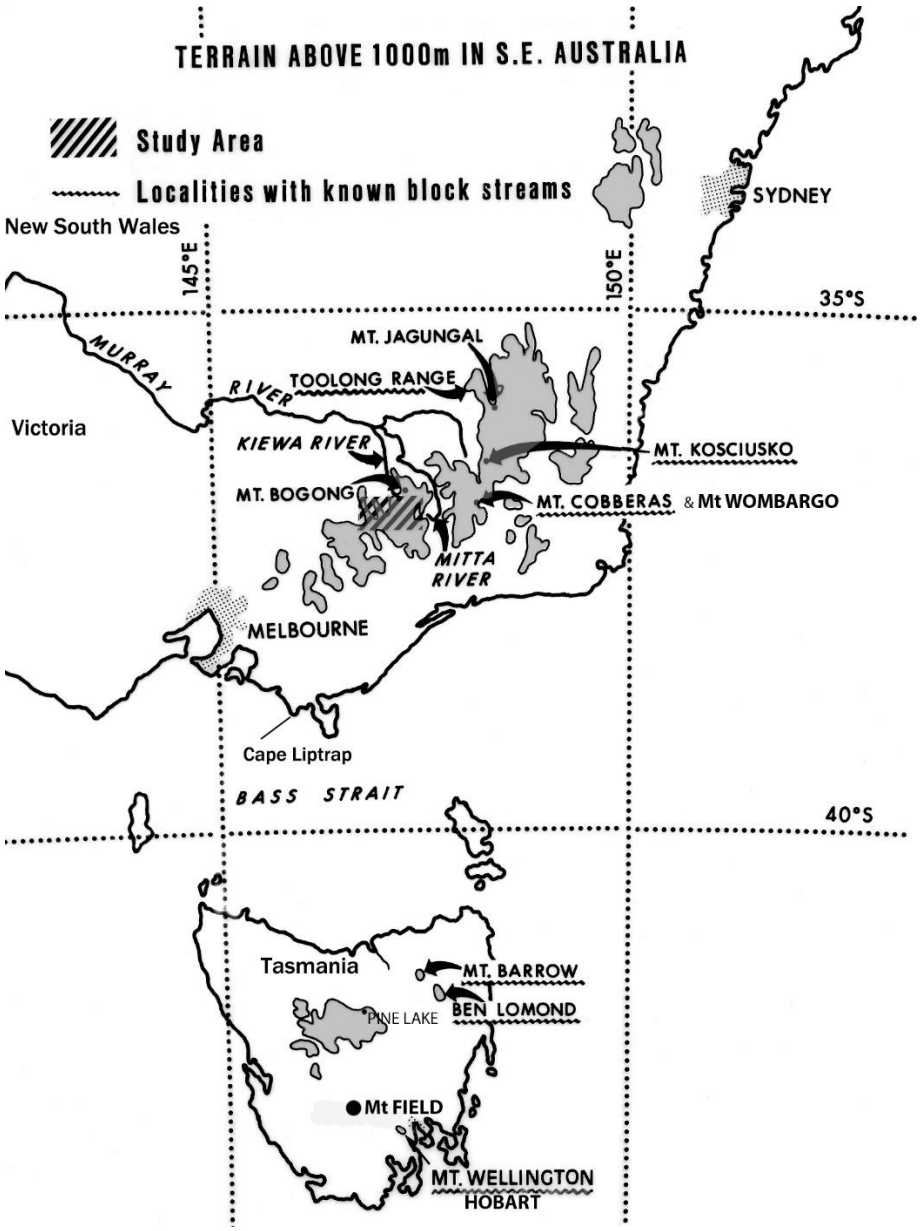
**Abstract**

A summary of evidence for prior cryo-conditioning in S. E. Australia.

*Keywords*: cryo-conditioning, permafrost, frost creep, gelifluction, blockslopes, blockstreams.



The Highlands of southeastern Australia possess a set of relict features which are consistent with prior permafrost and cryo-conditioning during the late Pleistocene. Data is summarized for specific examples in table one. The following figures are numbered for each column (location) in table one. Cryo-conditioning[1] is the modification of portions of these landscapes which possess susceptible bedrock and surface debris due to interaction with a thermal regime causing prolonged subsurface temperatures <0ºC, except for the seasonal thawing of the uppermost layer, the active layer.

Permafrost creep is the slow downhill mobilization of frozen, ice-rich debris and it has been the focus of research for the task force (in Europe) on Permafrost Creep and Rock Glacier Dynamics, since 1998. Wilfried Haeberli (2006)[2] reported on the nature of permafrost creep, its associated stratigraphy and its morphology. The stratigraphy/morphology of creeping permafrost, especially the active layer, correlate well with the open blockwork of relict blockslopes and blockstreams in the Australian Alps.

Haeberli (2006) and others have reported that steadily creeping perennially-frozen, ice-rich debris in mountain areas outside the arctic circle, possess an active layer which develops vertical sorting, with grainsize decreasing with depth. Corte (1966)[3] demonstrated the process of vertical sorting in the laboratory and also in field trials in permafrost terrain. Most relict block deposits with coarse, open, sub-angular debris at the surface, in the Australian Alps, exhibit vertical sorting with fining towards the base. A selection of these deposits is outlined in table one.

The term periglacial is not only vague, it lacks the context of adjacent glacial landforms in Victoria and it also lacks a specific signature on the landscape because the periglacial domain represents a broad range of environmental conditions. However, when Colin Thorn (2004)[4] asserted that freeze-thaw weathering lacks diagnostic characteristics, he may not have fully considered the textural effects of a sub-zero thermal regime on well jointed bedrock.

Vertical sorting of debris generated in a sub-zero thermal regime has been reported in mountain permafrost zones throughout the northern hemisphere by: Wahrhaftig (1949)[5], Krane and Mostler (2000)[6], Haeberli et al (2006), Hausmann et al (2007)[7] and Leopold et al (2011)[8]. Vertical sorting of relict blocky deposits in the highlands of southeastern Australia is well documented by Caine and Jennings (1968)[9] on the Toolong Range, Kosciuszko National Park and also within the blockfields of Ben Lomond and Mt Barrow by Nel Caine (1968)[10]. Vertical sorting has also been observed within a block glacis at Basalt Hill by Minty (2018)[11] and within an exposed road

section near Betts Creek, Kosciuszko National Park, (Minty 2021)[12]. Vertical sorting is evident in road sections through relict blockslopes on the northern slopes of Ben Lomond and Mt Barrow (Minty 2021)[13]. Also, sieving of auger returns extracted from a suspected relict gelifluction layer on Mt Nelse (1882m) on the Bogong High Plains, Victoria has revealed vertical sorting of material in a small grainsize range from cobbles to fine sand[14].

In addition to vertical sorting, the relict blockstreams and blockslopes of S.E. Australia possess other characteristics which are consistent with prior cryo-conditioning

i) Lateral Displacement. In most cases it can be demonstrated that lateral displacement of blockwork on gentle-moderate slopes (< the angle of repose) has occurred, for up to 1000m beyond the source bedrock boundaries.

ii) Thermokarst. This is the surface morphology resulting from the melt-out of interstitial/included ice from within the blockstreams/blockslopes. It seems to take several forms including: a) Broad deflation of the blockstream resulting in a concave cross-section. b) Furrows or linear depressions running downslope for tens or hundreds of metres and from 1 to 3m deep. These furrows are dendritic in plan and mimic an underlying drainage network. c) Pits or conical-broad depressions from 600mm deep to approx. 3m deep in large deposits.

iii) Imbrication is the regular stacking of tabular or platy blocks in a blockstream/blockslope, like a set of dominoes that have toppled downslope and onlap onto each other. This fabric suggests episodic movement consistent with seasonal thawing and fluidization of the active layer.

iv) Context. Other adjacent relict landforms. Frost heaved blocks of jointed bedrock on exposed, elevated bedrock surfaces are common in association with blockslopes down-slope. Also, these exposed ridges and summit flats generally exhibit terraced bedrock with a stepped profile. These features are consistent with cryoplanation in permafrost terrain as reported by Washburn (1975)[15] and illustrated for the Bogong High Plains[16].

v) Palaeoclimate Proxies. These studies are discussed in the book: *Kosciuszko Ice-Age Heritage*. They all point to cycles of very cold and very dry, windy conditions during the late Pleistocene with increasing aridity culminating at 17ka-22ka BP, when most of the blockslopes/blockstreams in S. E. Australia were last active[17].

Nel Caine (1983) reviewed his earlier work in northeastern Tasmania and concluded that the low gradients of the associated blockslopes was probably due to permafrost creep during the late Pleistocene[18].

Table One: **A Selection of relict cryogenic landforms consistent with prior permafrost in southeastern Australia**

| Location | Mt Field Tasmania | Sphinx Bluff, Ben Lomond, Tasmania | Carr Villa, Ben Lomond, Tasmania | Pine Lake, Tasmania | Basalt Hill, Bogong High Plains, Victoria | Mount Wombargo Eastern Victoria | Mount Little Higginbotham Victoria | Section Ridge, KNP, NSW | Toolong Range, KNP, NSW | Farm Ridge, KNP, NSW | Spencers Creek, KNP, NSW | Mount Kosciuszko KNP, NSW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Major Features | Blockslope & Rockglacier (Relict) | Blockslope & Rockglacier (Relict) | Compound Blockslope (Relict) | Blockslope & Block Glacis/ Relict Rockglacier | Blockslopes & relict Compound blockstreams | Vegetated Blockslopes, Blockstreams (Relict) | Blockslope & Block glacis (Relict) | Blockstreams & Blockslopes (Relict) | Blockstreams & vegetated blockslopes (Relict) | Blockslopes & Blockstreams (Relict) | Blockslope & Block glacis (Relict) | Blockslopes & Blockstreams (Relict) |
| Specific Location | 146°37.911'E 42°40.732'S | 147°44.0'E 41°36.529'S | 147°37.836'E 41°30.811'S | 146°44.823'E 41°42.284'S | 147°19.200'E 36°53.644 'S | 148°9.876'E 36°57.101'S | 147°9.660'E 36°59.544'S | 148°24.574'E 35°49.874'S | 148°21.513'E 36°8.036'S | 148°23.535'E 36°4.151'S | 148°19.976'E 36°25.960'S | 148°15.496'E 36°27.233'S |
| Elevation Range | 880-1140m | 1130-1330m | 1247-1360m | 1190-1300 | 1430-1640m | 1256-1510m | 1548-1730m | 1073-1230m | 1630-1670m | 1430-1545m | 1757-1780m | 1960-2090m |
| Rock type | Dolerite | Dolerite | Dolerite | Dolerite | Basalt | Rhyodacite | Basalt | Basalt | Basalt | Basalt | Granodiorite | Granodiorite |
| Rock Structure | Columnar max diam 2m | Columnar | Columnar max diam 2m | Columnar max diam 2m | Columnar max diam 0.5m | Columnar Max diam 1.0m est. | Columnar | Columnar max diam 1.0m | Columnar max diam 0.5m | Columnar | Tabular blocks to 4m | Tabular blocks to 4m |
| Gradient and Morphology | 60% blockslope merges into a lobate terrace 20% | 36% blockslope merges to compound lobes at 25% | 64% at head to 20% at toe. | 35% blockslope merges with 20% block glacis/R.R. | Dendritic, discont. Blockstreams ave grad. 25% - 46% | 33-38%grad. Dendritic set of blockstreams Concave x-s | Block glacii merge to blockslope with ave grad. 45-50% | Stepped blockstream Grad. mostly 33%-50%. Risers to 84% | Rectilinear blockstreams at 8%-15% with distal risers at 47% | Concave slope with ave gradient 30%. Long. Furrows | Blockslope 20-25% & distal block glacis 2-10% | Blockstream gradient 22% over 550m |
| Surface Texture | Imbricated blocks. Thermokarst pits 3m deep | Imbricated blockwork. Traces of transverse ripples | Imbricated blockwork; Thermokarst pits 3m deep. | Imbricated blockwork, Thermokarst; Transverse Ripples. | Imbricated; Vert. sorting; Transverse Ripples & pits to 1.0m | Open blockwork | Imbricated blockwork, Transverse Ripples, & pits to 1.5m | Imbricated blockwork, Transverse Ripples, & Thermokarst | Imbricated, Longitudinal Furrows to 2m & pits to 1m | Traces of transverse lobes in distal blockstream | Imbricated; broad vegetated depressions to 2-3m | Imbricated blockwork. Terraced bedrock Cryoplanation |
| Age | Late Pleistocene (Inferred) | Late Pleistocene (Inferred) | 22.1ka-498ka Radiometric Exposure dating | Late Pleistocene (Inferred) | Late Pleistocene (Inferred) | Late Pleistocene (Inferred) | 16.3ka-58.9ka radiometric | 21.3ka-22.7ka radiometric | <35ka C14 dating | Late Pleistocene (Inferred) | Late Pleistocene (Inferred) | Late Pleistocene (Inferred) |
| Authors Referred to | Minty, 2021, Report on cryogenic features at Mt Field.... **Academia** | Nel Caine, 1983 The Mountains of NE Tasmania Note pp112-114 | Barrows et al 2004, Quaternary Science Reviews, V23 | Minty,2021 Relict Cryogenic Landscape at Pine Lake, **Academia** | Minty,1989 MSc thesis, Abstract pub. Roy Soc NSW V 123, 1990 | Reference to J. A. Talent, 1965. Proc Roy Soc Vic V78 | Barrows et al 2004, Quaternary Science Reviews, V23 | Barrows et al 2004, Quaternary Science Reviews, V23 | Caine & Jennings, 1968, Proc Roy Soc NSW, V101 | Minty, 2021 Koscluszko Ice-Age Heritage. **Academia** | Minty, 2021 Koscluszko Ice-Age Heritage. **Academia** | Minty, 2021 Koscluszko Ice-Age Heritage. **Academia** |

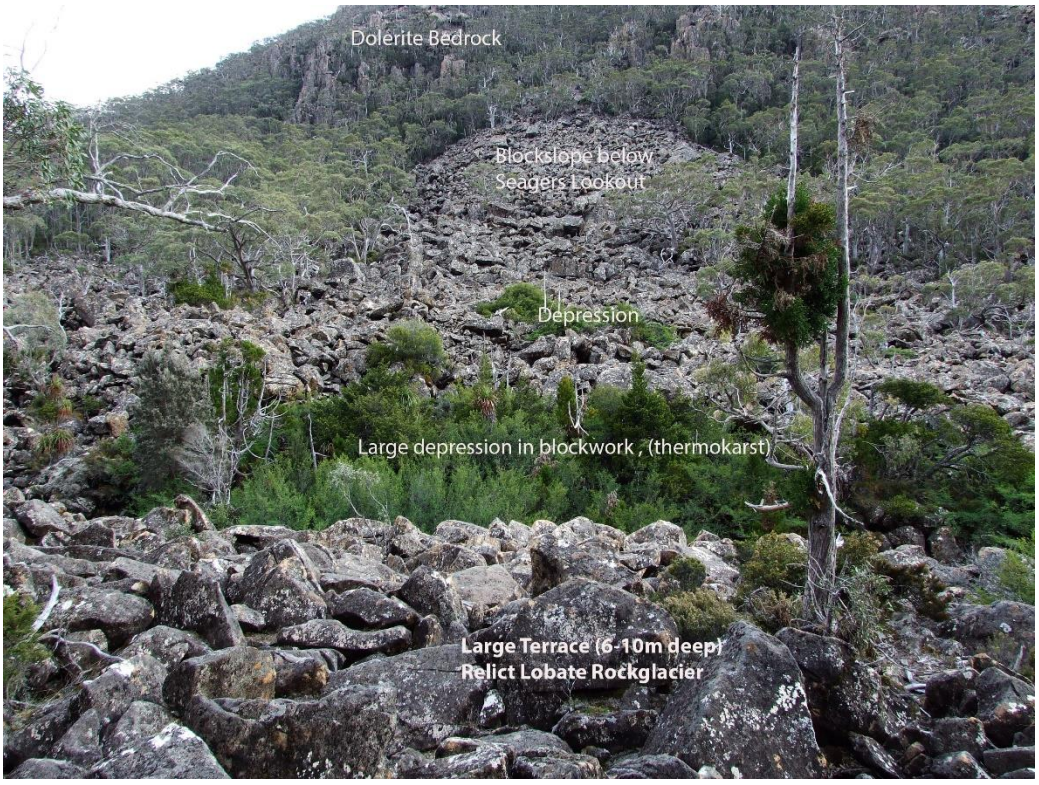



Figure 1 Mt Field , Tasmania

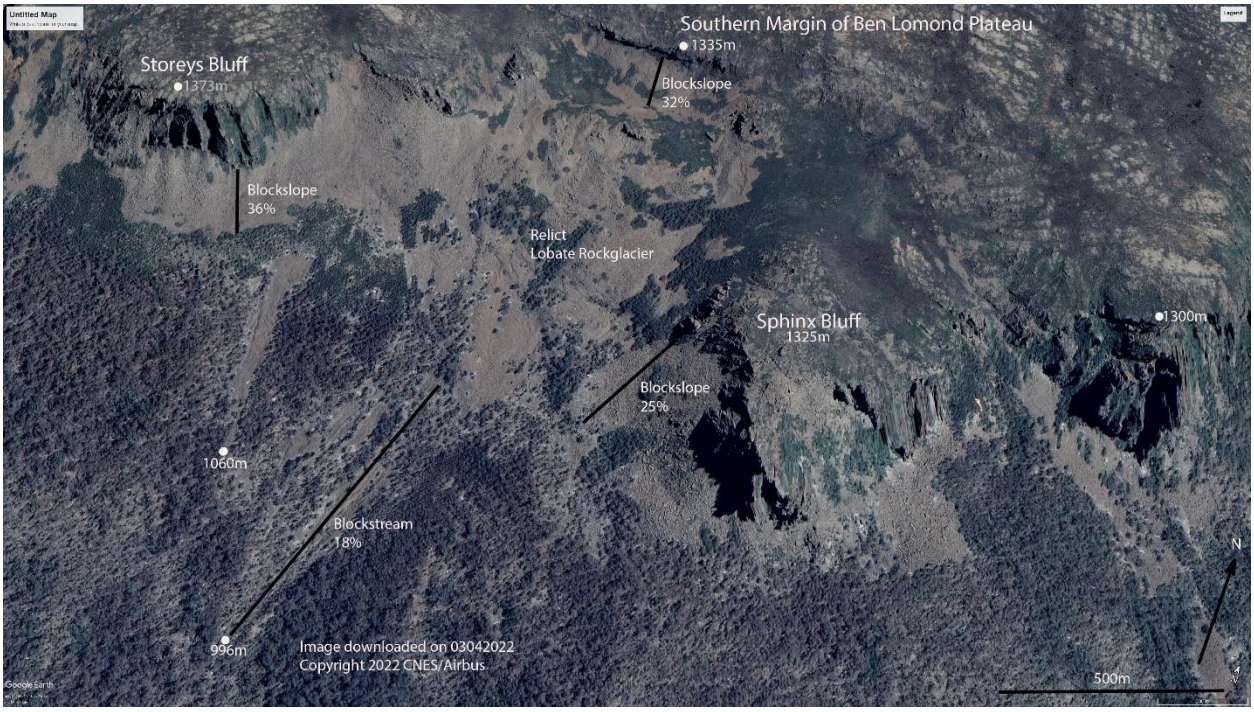



Figure 2 Sphinx Bluff, Blockfields and relict Lobate Rockglacier, Ben Lomond, Tasmania

Figure 3a Distal Toe of Carr Villa Blockslope, Ben Lomond, Tasmania

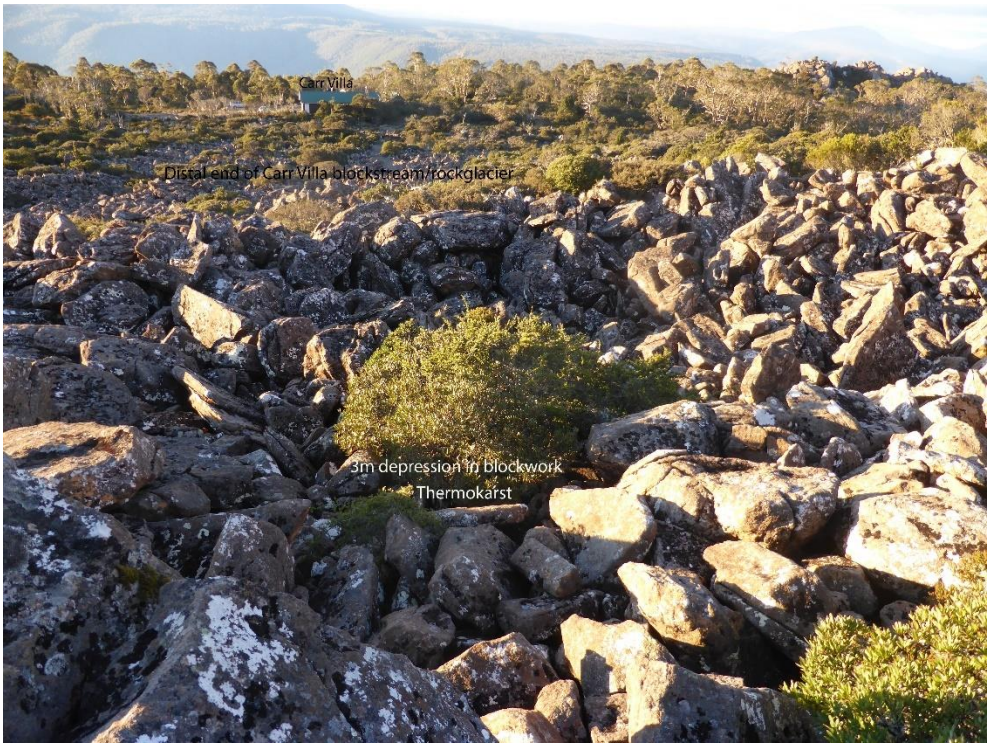



Figure 3b Thermokarst depression in blockwork on Carr Villa Blockslope, Ben Lomond.

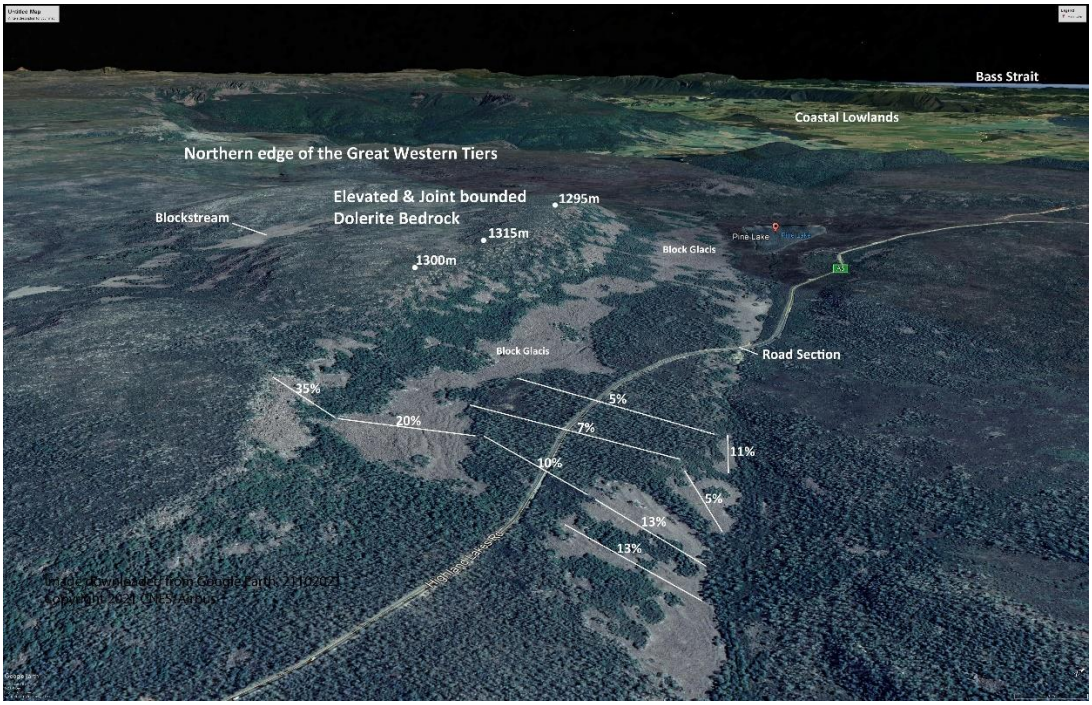



Figure 4 Overview of Blockslope terrain near Pine Lake, Tasmania

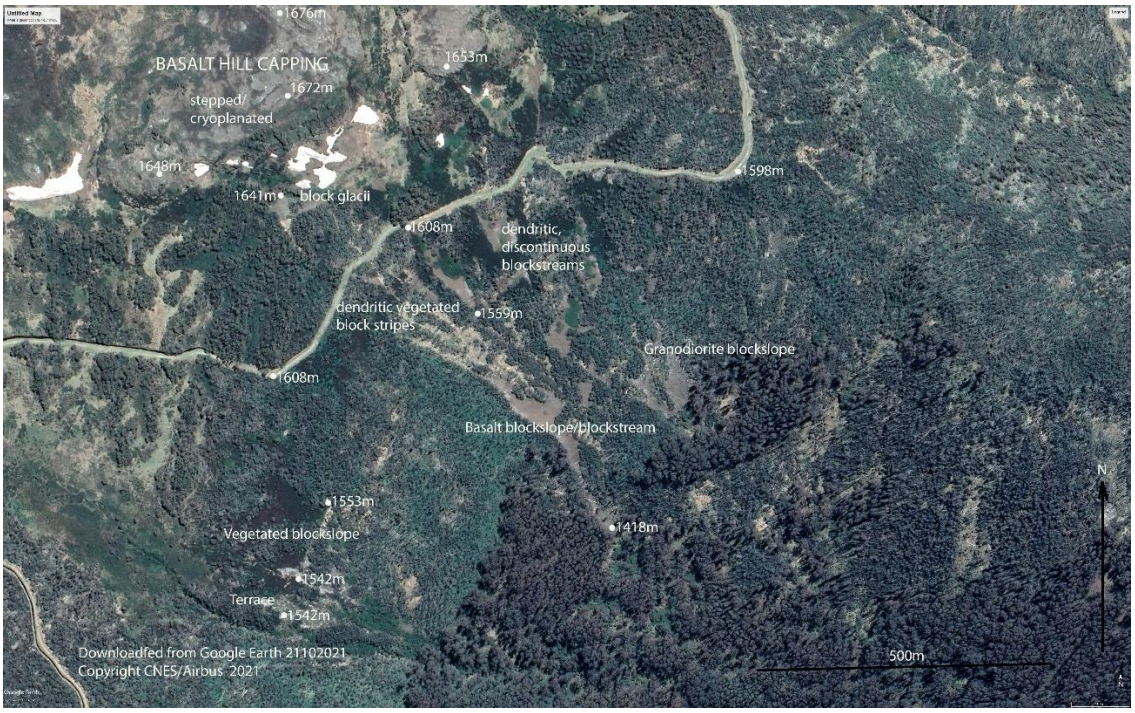



Figure 5 Overview of Basalt Hill Blockstreams on the Bogong High Plains, Victoria

Figure 6 Dendritic blockstreams SW of Mt Wombargo in eastern Victoria

Figure 7a Overview of block glacis and blockslope below Mt Little Higginbotham, northeastern Vic.

Figure 7b View up Blockslope with aqueduct in foreground

Figure 8 Steep, narrow blockstream below Section Ridge, Kosciuszko National Park, NSW.

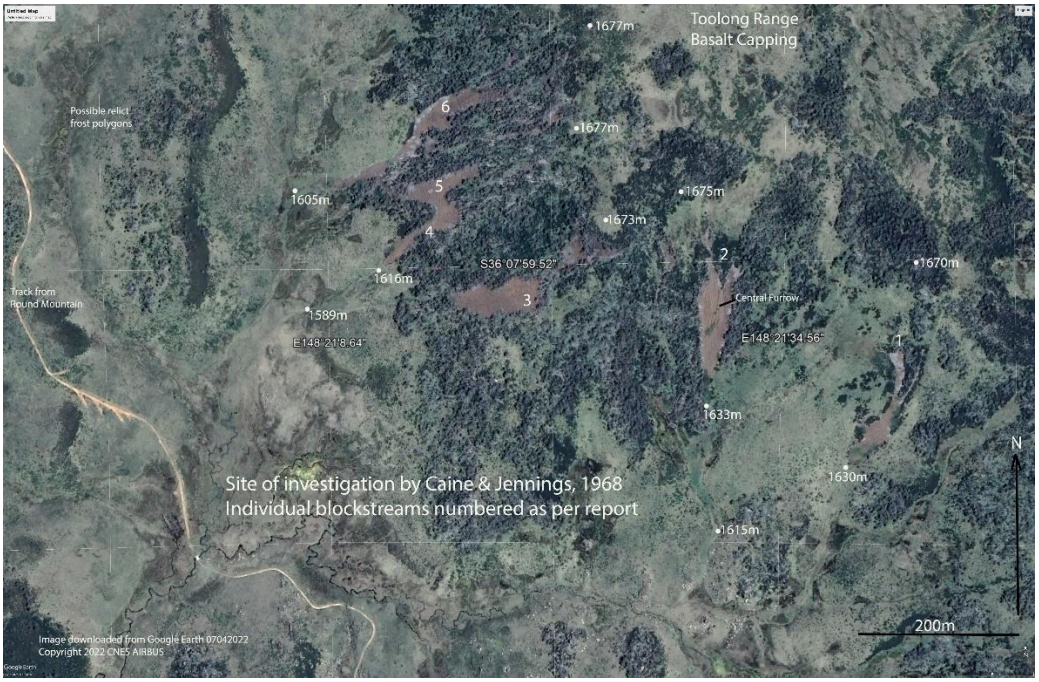



Figure 9 Overview of the Blockstreams investigated by Caine & Jennings, 1968, KNP.

Figure 10 Blockstreams below the SE edge of Farm Ridge, Kosciuszko National Park, NSW.

Figure 11a  Blockslope/Block Glacis at head of Spencers Ck and below Mt Guthrie, KNP.

Figure 11b  View of imbricated granodiorite blocks in blockslope below Mt Guthrie, KNP.

Figure 12 Blockstreams and vegetated blockslopes on western flank of Mt Kosciuszko, KNP.

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